ECONOMIC SERIES NO. 4.

BRITISH MUSEUM (NATURAL HISTORY)

MOSQUITOES

AND THEIR RELATION TO DISEASE

THEIR LIFE-HISTORY, HABITS AND CONTROL

BY

F. W. EDWARDS, B.A.

ASSISTANT IN THE DEPARTMENT OF ENTOMOLOGY,
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THIRD EDITION

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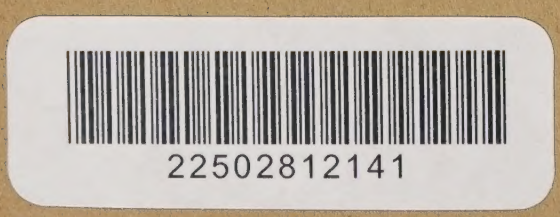
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MOSQUITOES AND THEIR RELATION TO DISEASE;

THEIR LIFE-HISTORY, HABITS AND CONTROL.

WHAT IS A MOSQUITO?

THERE has been a widespread idea that a mosquito is a particular species of insect inhabiting the tropics. This idea, however, is very far from the exact truth. There are, in reality, about a thousand different kinds of mosquitoes known, and they inhabit every country of the world; in Britain we have no fewer than twenty-one different kinds. The term *mosquito*, which is really synonymous with the English *gnat*, is used to denote any two-winged fly with a long blood-sucking proboscis projecting from the front of the head, and with wings, the veins of which are arranged on the same plan as in the common house-gnat. The term might, perhaps, be restricted further and applied to the females only of these insects, since it is members of that sex which alone suck blood, the males feeding—if at all—on the juices of plants.

As may be gathered from the above definition, mosquitoes may be distinguished from other two-winged flies by the structure of their wings. The chief point to notice is that towards the apex of the wing there are two bifurcated veins separated from one another by a single simple vein; apart from this, the veins are covered with scales. These two characters combined will readily distinguish mosquitoes from all other flies, such as midges or small daddy-long-legs, for which they might possibly be mistaken, but their slender build, long legs and long biting proboscis mark them off at once from other biting flies.

THE LIFE-HISTORY OF MOSQUITOES.

The life of mosquitoes, as in the case of other flies, as well as butterflies, beetles and many other insects, is divided into four sharply defined stages. These are (1) the egg, (2) the larva, (3) the pupa, and (4) the adult insect.

The *eggs* are elongate, blackish, about 1 millimetre or less in length, and are usually laid on the surface of water, though in one group they are deposited on the dry ground. The females of some species, such as *Culex*, form their eggs into "rafts" by glueing

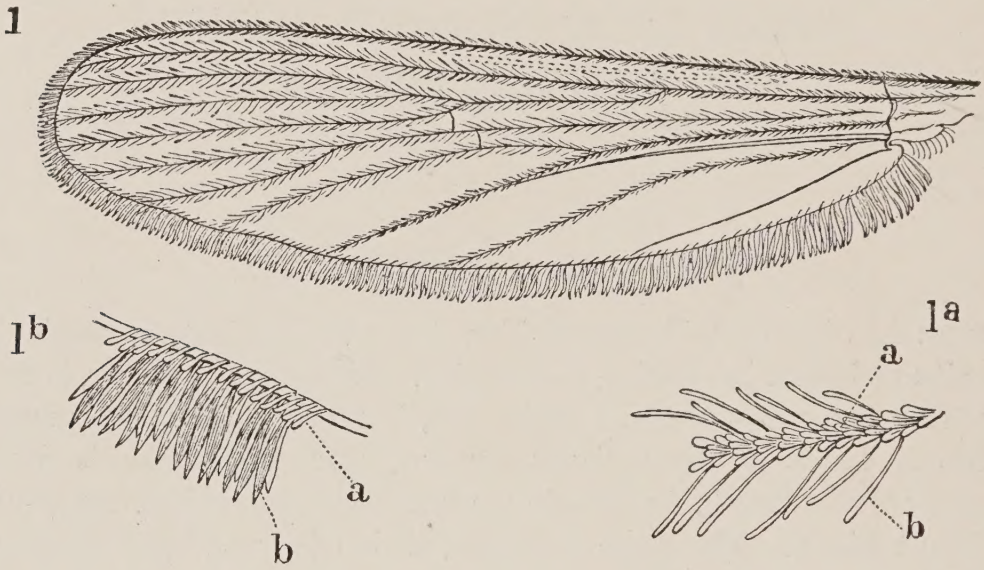


FIG. 1.—WING OF THE COMMON HOUSE-GNAT OR MOSQUITO (*Culex pipiens*). × ABOUT 16.

1a.—Portion of 2nd longitudinal vein, greatly enlarged, to show the covering of scales: (*a*) median vein-scales; (*b*) lateral.

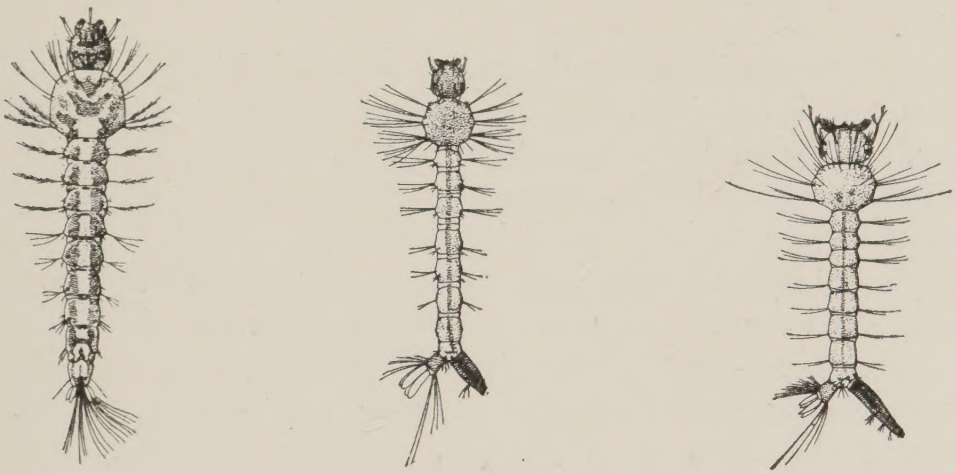
1b.—Portion of hind margin of wing, greatly enlarged, to show the fringe: (*a*) border-scales; (*b*) fringe-scales.

them together. The eggs of *Anopheles* differ from those of other mosquitoes in having special air-chambers which help them to float.

The *larval* period is invariably passed in water, where the larvae obtain their food, consisting usually of minute particles of animal or vegetable matter, which are swept into the mouth by large brush-like organs continuously kept in motion. A few species are predaceous, and many others, if their normal food supply fails, do not hesitate to become cannibals. Although passing their existence in water, the larvae are incapable of extracting their supply of oxygen from it, and consequently it is necessary for them to come frequently into contact with atmospheric air for purposes of breathing. This is effected by the

larva wriggling to the surface of the water * and hanging on to the surface film by the breathing organ, which is situated at the tail end. Although the larvae of the different species of mosquitoes vary considerably in the frequency with which they come up to breathe, there is none that can live for more than a few hours when deprived of access to the air.

The larval period is one of growth, during which the skin is cast three times. At the end of this time—which may vary in length from a few days to several months, according to th e con ditions of temperature—growth is complete, and the larva casts its



(*a*) (*b*) (*c*)

FIG. 2.—LARVAE OF MOSQUITOES.

(*a*) *Anopheles maculipennis*, Mg. ; (*b*) *Stegomyia fasciata*, F. ; (*c*) *Culex fatigans*, Wied. × 4.

skin a fourth time to become a *pupa*. The pupa is a very different-looking object from the larva ; instead of being elongate and more or less cylindrical, it is of a form which has very aptly been described as "comma-shaped," consisting of a very large "head" with a "tail" attached ; at the end of the "tail" are a pair of "paddles,' which assist the pupa in its extremely active movements through the water. The pupa takes no food, but like the larva it breathes air from the surface of the water ; its breathing organs, however, instead of being situated at the tail end are placed close to the head.

* The only exceptions to this rule are to be found in a few very remarkable mosquito larvae which are specially modified for obtaining a supply of air from the roots of water plants. Only one of our British species belongs to this group.

At the end of a few days (from one to five) the pupa comes to rest at the surface of the water, the skin splits along the back and the mosquito emerges.

Such, in outline, is the general life-history of all mosquitoes; but, as might naturally be expected, there is a great deal of variation in detail both in the structure and the habits of these insects. For our present purpose it is possible to make a biological classification of mosquitoes, dividing them into (*a*) domestic species, (*b*) stream and pool-breeding species, (*c*) sylvan species, (*d*) swamp and marsh-breeding species. This classification will be useful for practical purposes, although, of course, it is not exact.

(*a*) **Domestic Mosquitoes.**—Under this heading are included those species which are more or less definitely associated with man, and breed by preference, if not exclusively, within or close to towns and villages. The best example of this group is the yellow fever mosquito, but it includes also several of the malaria-carrying *Anopheles*, and *Culex fatigans*, the species which is chiefly responsible for the spread of elephantiasis, in addition to the common house-gnat of Europe which is at times very troublesome. The breeding places are to be found in rain-water barrels, roof-gutters, cesspools, small puddles, water in old tins, in fact, in any collection of water about houses, no matter how small, no matter whether clean or foul, to which the female mosquito can obtain access to lay her eggs. In temperate regions the females of this group live through the winter and commence egg-laying in the first warm days of spring.

(*b*) **Stream and Pool Mosquitoes.**—This group consists chiefly of the malaria-carriers of the genus *Anopheles*, the larvae of one or other of which are to be found in almost every stream, rapid or sluggish, and in nearly every pool, small or large. They occur chiefly along the weedy edges, where the growth of algae or other plants serves at once to provide them with a plentiful supply of food and to protect them from the attacks of enemies.

(*c*) **Sylvan Mosquitoes.**—Here we include a great number of species which have, as a whole, very varied habits, although each particular form varies but little, some indeed being among the most specialised mosquitoes as regards their mode of life. Some live (as larvae) in the water in holes in trees or in the broken ends of bamboos; others at the bases of the leaves of

bromelias, bananas, pineapples and other plants; others again in the leaves of pitcher-plants. Although very interesting scientifically, by far the greater number of these species are harmless; many of them do not even bite, but such breeding places in the neighbourhood of towns must not be overlooked, as the domestic species are liable to resort to them when others are not available. We have only three tree-hole breeders in Britain, two of which are very vicious in their attacks.

Under this heading may also be included those species whose larvae occur in early spring in temporary pools of rain-water in woods and on heaths, and in cold countries in the pools formed by the melting snows. These species, particularly in Arctic regions, often occur in enormous numbers, and are amongst the most bloodthirsty of all the mosquitoes, though at present that is the most serious charge that can be made against them, as none of them have yet been incriminated as disease carriers. They have, as a rule, only one brood a year, which are hatched out in the spring, living on all through the summer and depositing their eggs in the dry hollows which will, during the winter, again become filled with water. About half of our British species belong to this group.

(*d*) **Swamp Mosquitoes.**—Allied in some respects to those last mentioned, are the species which breed in extensive and more or less permanent swamps, shallow inland lakes, or salt marshes along the coast. *Anopheles* is represented in this group, but they are not as a rule disease carriers, although in many regions they occur in such vast swarms as to constitute a serious pest. They differ from those of the preceding groups in their power of migration, cases having been recorded in which large clouds of them migrated a distance of at least fifty miles, while in other instances they have been known to make a nightly invasion of towns situated a mile or more distant from their breeding places.

MOSQUITOES AND DISEASE.

It has long been recognised that the most serious obstacles to the settlement of the tropics by the white man are the diseases which are rife in those regions, but it is only since the early years of the present century that mosquitoes have been shown to be the agents in the spread of some of the most devastating of these maladies. The blood parasites which are the actual causes of the

ailments cannot exist continuously in one host, but require for their full development alternating periods in man and a mosquito; they are drawn up with the blood when the mosquito bites an infected patient, and if, after an interval of a week or so, the same mosquito bites a healthy individual the disease can and probably will be transmitted to him.

The four diseases which have now been definitely proved to be carried by these insects are Malaria, Yellow Fever, Elephantiasis and Dengue Fever; in addition there are some other cases in which mosquitoes are under suspicion.

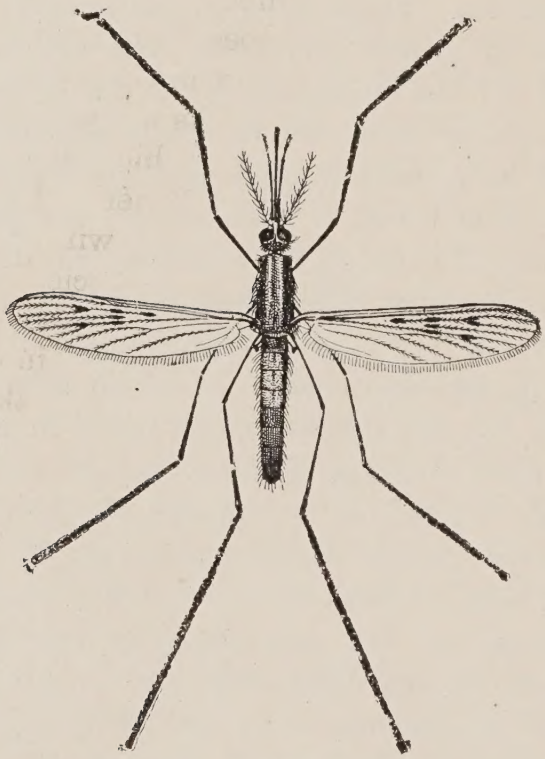


FIG. 3.—*Anopheles maculipennis*, Mg. ♀. × 4.
One of the carriers of malaria in Southern Europe.

Mosquitoes and Malaria.—Through the labours of a number of investigators, of whom special mention must be made of Grassi, Laveran, Manson and Ross, the cause of this widely spread tropical and subtropical disease was shown, in the year 1898, to be an intracorpuscular blood-parasite, which is invariably carried from man to man through the medium of certain mosquitoes. Further and more detailed work since that time tends to indicate that the different forms of malaria may be carried by

particular species of mosquitoes, but this is not yet sufficiently established. Whether this be true or not, it has been proved by countless experiments that all the mosquitoes which are capable of carrying human malaria belong to a distinct group, the genus *Anopheles;* while even within this group there are many species which are not, or appear not to be, disease carriers.

The *Anopheles* mosquitoes can be distinguished from the others by several characteristics: (1) the position of rest: the whole body extends *in a straight line* at an angle with the surface on which the mosquito is resting; in other mosquitoes the body-line is bent, owing to the more rounded or "humped" shape of the thorax;

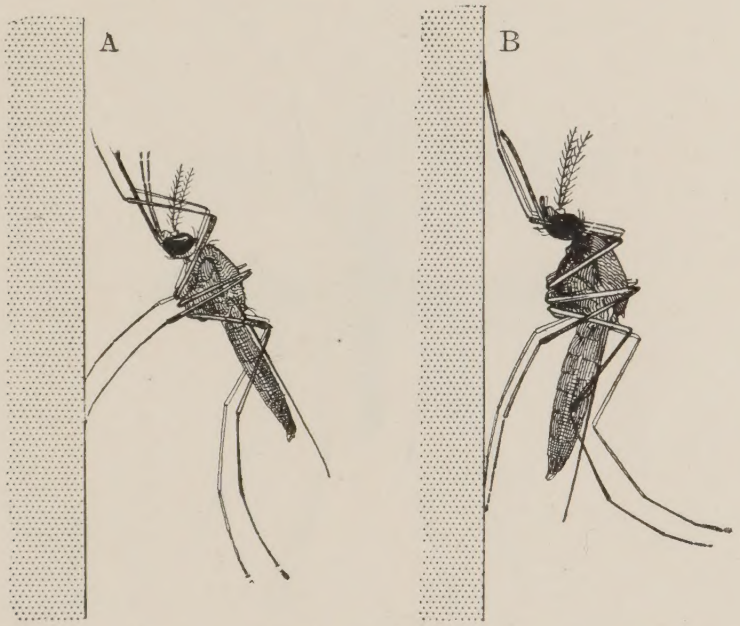


FIG. 4.—SITTING POSTURES ADOPTED BY MOSQUITOES.
(A) *Anopheles;* (B) *Culex.*

(2) in the great majority of the *Anopheles* the wings are spotted, whereas in the great majority of the others they are not; (3) in the female *Anopheles* the palpi are as long as the proboscis, while in most of the other genera they are much shorter; (4) when viewed under a microscope most mosquitoes are seen to have the abdomen covered with scales like those on a butterfly's wing, but in nearly all *Anopheles* these scales are absent; (5) the larvae of *Anopheles* when at rest lie parallel with and touching the surface of the water, being held to the surface-film by a number of remarkable rosette-shaped tufts; the breathing organ is small.

Other mosquitoes have larvae which hang head downwards in the water when at rest, and have no rosettes, but on the other hand have the breathing organ developed into a tube.

There are about one hundred species of *Anopheles* known from different parts of the world. We have three in Britain; two of these have been proved to spread malaria in South Europe, while the third has recently been shown capable of carrying the infection. The local outbreaks of malaria in this country during the war were due to the reintroduction of the malarial parasite (which was believed to have been extinct in Britain prior to 1914) by returned

FIG. 5.—*Stegomyia fasciata*, F. (OR *Aëdes argenteus*, Poiret.). ♀ × 4.

The only carrier of yellow fever.

soldiers suffering from the disease. The infection was conveyed from such individuals to healthy persons through the agency of our native mosquitoes. There is probably very little danger now of any serious spread of these outbreaks.

The bite of most species of *Anopheles* is inflicted almost exclusively at dusk or during the night, but the species will bite during the day if disturbed.

Mosquitoes and Yellow Fever.—The ravages of yellow

fever in South and Central America, and the part played by the disease in causing the failure of the early attempts to construct the Panama Canal, are well known, as is the fact that the disease is carried by a mosquito. The mosquito theory was first put forward by Dr. Finlay of Havana so long ago as 1881, and he adduced some strong evidence in support of his views; but definite and conclusive proof was not obtained until 1900, when the United States Army Commission, under the direction of Dr. Reed, solved

FIG. 6.—*Culex fatigans*, Wied. ♀. × 4.

The chief carrier of Elephantiasis.

the problem in Cuba. A number of subsequent investigations have been made, with confirmatory results, so that it may now be stated with certainty that Yellow Fever is spread only through the agency of one particular kind of mosquito, the species known to science as *Stegomyia fasciata* or *Aëdes argenteus*. Search for the parasite actually causing the disease was for long unsuccessful, but it is now believed that an organism discovered by Dr. Noguchi in 1919 is responsible. It is a blood-parasite with a definite life-history, requiring to live first in the mosquito and then in man in

order to complete its development. The incriminated insect has only once (in 1919) been taken wild in this country, but it may formerly have occurred or been introduced.

The Yellow Fever mosquito is a beautiful insect, strikingly marked with black and white; its most characteristic feature, by means of which it may be distinguished from every other mosquito, is the lyre-shaped white mark on the thorax. Apart from its conspicuous coloration, it differs from the malaria mosquitoes in the points already indicated. It is a purely domestic mosquito, rarely found far away from towns or villages, and like other brightly coloured mosquitoes it bites chiefly during the day-time, only occasionally at night. It is practically universally distributed in tropical and sub-tropical regions, but fortunately the disease which it conveys is much more restricted in its range.

Mosquitoes and Elephantiasis.—This is another tropical disease which frequently, though not necessarily, results from the presence of the worms known as *Filariae* in the blood. Manson in 1878 was the first to suggest and prove the carriage of the worms by mosquitoes, though it was not until much later, through the researches of Annett, Dutton and Todd (1901), Lebredo (1905) and Fülleborn (1908) that the entire life-history was elucidated. In this case the parasite, owing to its large size, cannot be introduced directly into the blood while the mosquito is in the act of biting, but it has been ascertained that it escapes from the mosquito while the latter is so engaged, and afterwards find its own way through the skin of its victim.

A number of different mosquitoes have been proved to be capable of carrying these worms, including *Stegomyia fasciata* and several species of *Anopheles*, but the chief carrier throughout the tropics appears to be the species known as *Culex fatigans*. This is almost exactly like *Culex pipiens*, the common house-gnat of Europe; it is a reddish-brown or dark brown insect, with dark legs and six transverse whitish bands on the abdomen. Apart from these bands it has no special markings. Like the yellow fever mosquito it is domestic, but not quite exclusively so. Like its European relative it bites exclusively at night; and in connection with this habit it is a remarkable fact that the embryo worms show a definite periodicity, coming close under the skin at night and retiring further into the body during the day-time.

THE CONTROL OF MOSQUITOES.

Prevention of Bites.—Although not sufficient in itself, it is often advisable to supplement other measures by adopting some means of preventing the attacks of mosquitoes. Such measures are particularly applicable to those with nocturnal habits, and can be used with good effect against *Anopheles*.

(*a*) All windows and doors may be covered with a fine wire gauze and kept closed from sunset to sunrise, a plan which has been largely adopted in Panama ; or the ordinary mosquito curtain may be used to protect the sleeper.

(*b*) In addition to the screening methods, and for protection against day-flying mosquitoes, such as *Stegomyia fasciata*, or the swarms of sylvan or swamp-breeding species, a variety of substances have been recommended for rubbing into the skin of the exposed parts. Some of those which have given the best results are :—*

(i) Light wood oil, 33 per cent. in a wax preparation.
(ii) Castor oil, alcohol and oil of lavender in equal parts.
(iii) Essential oil of oranges, 30 gms. ; liquid vaseline, 120 gms.
(iv) Oil of thyme and water.
(v) In military camps, where the essential oils mentioned above would be too scarce or expensive to use in large quantities, pure kerosene has been found to be efficacious, but of course the smell is objectionable. All these substances are transient in their effects when the climatic conditions are such as to cause much perspiration.

(*c*) It has often been noticed that some mosquitoes more readily attack persons wearing dark clothing.

Cure for Bites.—Some persons find that an application of benzene will allay the irritation and swelling due to mosquito bites. Ammonia has also been used, but the reaction of different individuals varies greatly, both to bites and to curative applications.

DESTRUCTION OF ADULTS.

Traps.—Large numbers of mosquitoes may sometimes be caught by placing suitable traps in cool shady places where they

* See Bacot and Talbot, " Parasitology," x. p. 221 (1919).

are likely to retire during the day. A large box with one end open placed among bushes makes a good trap.

Destruction of Cover.—Mosquitoes frequently take shelter in long grass and other coarse herbage, and if it is practicable to burn this the insects will either be destroyed or driven to seek shelter elsewhere.

Sprays.—In temperate regions the females of several species pass the winter in a torpid state, remaining on the walls of cellars and similar places, and there they may easily be destroyed by spraying the walls with some substance poisonous to them. Similar methods may also be used against those which "aestivate" in hot dry countries. Giemsa recommends either:—

(i) $2\frac{1}{2}$ per cent. solution of potash soap; or
(ii) A solution of 3 drams of medical soda soap in $1\frac{3}{4}$ pints of water containing 11 drams of formalin. The smell of the formalin may be removed by allowing ammonia to evaporate.

A liquid prepared by the Russian scientist, Dr. Malinin, has been extensively and successfully used in Caucasia for destruction of mosquitoes in barracks and camps, by spraying on the walls, and also the beds, clothing and persons of the soldiers.*

Fumigants.—As an alternative to spraying, fumigation may be employed in order to rid rooms of mosquitoes. Cresyl has been recommended as a good fumigant; the quantity required is about 75 grains for every 35 cubic feet of space, and it need only be left to volatilise in the closed room. It has the advantage of being innocuous to human beings.

Natural Enemies.—A great variety of other animals are known to prey upon adult mosquitoes, such as predaceous flies, wasps, dragonflies, spiders, lizards, birds and bats. The value of swallows was recognised even at the end of the eighteenth century, when the Commune of Marsciano (Umbria) asked for a papal decree prohibiting the destruction of these birds, on the ground that their being killed in large numbers for food caused an increase in the number of noxious winged insects and so made the place unhealthy. It is doubtful, however, if these enemies can be made use of artificially with any success.

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* *Vide* "Review of Applied Entomology," Vol. III. ser. B, July 1915, pp. 105–106.

DESTRUCTION OF LARVAE AND BREEDING PLACES.

The destruction of mosquito larvae or of places where they are likely to live is much the most satisfactory way of dealing with these pests. The general principles adopted in this method of attack are: (i) the removal of possible breeding places; (ii) the effective screening of collections of water which cannot be removed; (iii) the utilisation of natural enemies, which are numerous; (iv) where these methods are not practicable, and for supplementing them, the application of larvicides, either in the form of oil which will form a film on the surface of the water and so prevent the larvae from reaching the surface to breathe, or of substances which, when mixed with the water, will kill the larvae.

The great diversity of the breeding habits of mosquitoes has already been referred to, and it is obvious that each of the classes described will require special measures for their extermination. We will consider them in turn.

Domestic Species.—The most important and effective control work is the elimination of breeding places. Any small collection of water in old tins, bottles, rain-water puddles, etc., should be removed. Vessels used for storing water for household purposes should be kept covered, and should be emptied at least once a week, being allowed to become thoroughly dry before being refilled. This precaution is necessary in order to get rid of eggs or young larvae which are very liable to cling to the wet surface of the vessel. Careful attention must be given to roof-gutters to see that no rain-water is allowed to accumulate in sagging ends. Holes in trees and similar places in the immediate neighbourhood should be filled in. Rain-water barrels and storage tanks should be effectively screened, oiled or stocked with small fish of the kinds which are known to prey on mosquito larvae; or copper sulphate may be added to the water in the proportion of one part to 5,000; this will not affect the drinking qualities of the water and will kill off all larvae. Powdered calomel has also been recommended as a good larvicide, but it should only be used in very small quantities owing to its poisonous nature. In covered cisterns and wells another good larvicide has been found to be flake naphthalene, in the proportion of half a gram to four litres of water. Cesspools

are often prolific breeding places, and may be dealt with similarly.

Even when all the above precautions have been taken it is probable that some breeding places will remain overlooked or inaccessible, and in order to prevent the mosquitoes utilising these it is desirable to provide trap breeding places. Earthenware pots or bamboo joints placed in shady positions and filled with water are effective; they should be emptied out as soon as young larvae make their appearance.

Stream and Pool Species.—For these forms drainage is the most effective method of control, and in the case of some species of *Anopheles* which live in rapid hill streams, subsoil drainage seems to be the only method possible; it has been resorted to with marked success by Watson in the Federated Malay States. Considerations of expense and other circumstances will, however, often prevent its application on a large scale.

In open stagnant pools, or slow-moving streams, minnows and other small fish and aquatic insects are a valuable aid in keeping *Anopheles* and other mosquitoes under control, and have sometimes been artificially introduced with successful results; but they are not of much use where there is any considerable quantity of algae or other vegetation present, and reliance should never be placed on them alone. Besides fish, ducks have been found very efficacious.

Oiling the surface of the water with kerosene, petroleum or some other oil is most important, and is the method which has been used perhaps more than any other. Exact prescription cannot be given as to the amount to be applied, owing to the variation in density and spreading qualities, but enough should be used to form a complete film on the surface. With the lighter oils spraying is the best method of application, but if heavier oils, such as sunflower oil, are used they are apt to collect into globules and may have to be spread on the water with a cloth or with brooms, instead of or after spraying. The disadvantage of the oiling method is that the larvae can often remain at the bottom long enough for the oil-film to become discontinuous, which soon takes place in a high wind. Apart from this, oiling is not satisfactory for the weedy margins of ponds and streams, and it is often necessary, therefore, to employ a larvicide which will mix with the water and kill the larvae in it.

A great variety of miscible larvicides have been recommended. The following preparation has been used with great success in the Panama Canal zone :—

"150 gallons of carbolic acid is heated in a tank to a temperature of 212° F. ; then 150 lbs. of powdered or finely broken resin is poured in ; 30 lbs. of caustic soda is then added and solution kept at 212° F. until a perfectly dark emulsion, without sediment, is obtained. The mixture is thoroughly stirred from the time the resin is put in until the end."

One part of this emulsion in 5,000 parts of water is said to be sufficient to kill *Anopheles* larvae in from five to ten minutes, or even less. The emulsion is diluted one-sixth, and sprayed on to the water, and can be used even in streams with a moderate current.

A cheap and very effective miscible larvicide is "White Cross disinfectant." Mr. J. F. Marshall finds that one part of this liquid in 30,000 parts of the water is sufficient to destroy larvae of *Aëdes detritus*.

Sylvan Species.—For these species the method of attack should consist in filling in hollows in trees, and collecting and burning in the late autumn the dead leaves, etc., from all hollows in which rain-water is likely to collect in the winter. Alternatively to the latter, the water in the hollows may be well oiled or treated with larvicide in the early spring.

Swamp Species.—Oiling and other methods can sometimes be used,* but the only effectual and permanent cure for these pests is drainage ; the initial outlay on this may be heavy, but in some cases, as for example the salt marshes of New Jersey, the expense has been much more than repaid through the enhanced value of the reclaimed land. The salt-marsh species only breed in salt or brackish water which has been allowed to stagnate ; an important preventive measure is therefore to keep all ditches and sluices in such order that the sea water can circulate freely.

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* In the salt marshes near Portsmouth Dr. D. H. C. Given has obtained good results by applying in considerable quantity a mixture of light shale oil and heavy fuel oil, and firing the mixture. This not only destroys the larvae, but helps to dry up the water, and burns eggs that may be clinging to vegetation. The oil used is dockyard waste oil, and can be obtained in large quantity at slight cost.

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